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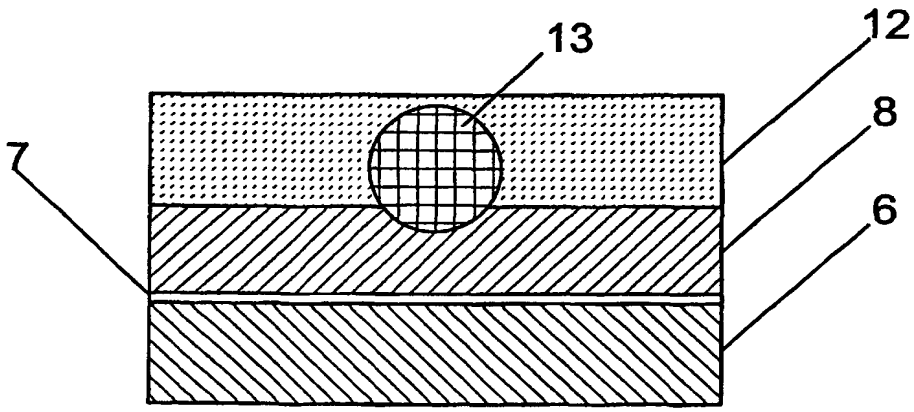
Published
With international search report.

(54) Title: WAVEGUIDE FOR AN OPTICAL CIRCUIT AND METHOD OF FABRICATION THEREOF

(57) Abstract

A waveguide for an optical circuit comprises a substrate; a buffer layer formed on the substrate; a doped lower cladding layer formed on the buffer layer; a doped waveguide core formed on the lower cladding layer; and a doped upper cladding layer embedding the waveguide core. The waveguide core includes mobile dopant ions which have diffused into the upper cladding layer and the lower cladding layer to form an ion diffusion region around said waveguide core such that the waveguide core boundary walls are substantially smooth. A waveguide core may be formed which is substantially symmetric about its core axis. Methods of fabricating the waveguide are also described.



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INTERNATIONAL SEARCH REPORT

Int. Application No
PCT/GB 00/00322

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/13

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 008, no. 260 (C-254), 29 November 1984 (1984-11-29) & JP 59 137346 A (NIPPON DENSHIN DENWA KOSHA), 7 August 1984 (1984-08-07) abstract ---	1-80
Y	SCHMIDTCHEN J ET AL: "GERMANIUM-DIFFUSED WAVEGUIDES IN SILICON FOR = 1.3 UM AND = 1.55 UM WITH LOSSES BELOW 0.5 DB/CM" IEEE PHOTONICS TECHNOLOGY LETTERS,US,IEEE INC. NEW YORK, vol. 4, no. 8, 1 August 1992 (1992-08-01), pages 875-877, XP000293620 ISSN: 1041-1135 the whole document --- -/--	1-80

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 May 2000	24/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jakober, F

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	"BURIED TI IN-DIFFUSED WAVEGUIDE ON LITHIUM NIOBATE" IBM TECHNICAL DISCLOSURE BULLETIN,US,IBM CORP. NEW YORK, vol. 33, no. 3A, 1 August 1990 (1990-08-01), page 199 XP000123902 ISSN: 0018-8689 the whole document	1-80
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 045 (P-430), 21 February 1986 (1986-02-21) & JP 60 191208 A (SHIYOUJIROU KAWAKAMI;OTHERS: 01), 28 September 1985 (1985-09-28) abstract	1-80
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 342 (P-635), 10 November 1987 (1987-11-10) & JP 62 124511 A (NIPPON TELEGR & TELEPH CORP), 5 June 1987 (1987-06-05) abstract	1-80

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/00322

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 59137346 A	07-08-1984	JP 1518949 C	29-09-1989
		JP 63065619 B	16-12-1988
JP 60191208 A	28-09-1985	JP 1830657 C	15-03-1994
		JP 5031123 B	11-05-1993
JP 62124511 A	05-06-1987	JP 2622108 B	18-06-1997

P. :NT COOPERATION TREA.

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
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Date of mailing (day/month/year) 03 October 2000 (03.10.00)	
International application No. PCT/GB00/00322	**Applicant's or agent's file reference** P23051A/VSL/CLF/PPP
International filing date (day/month/year) 07 February 2000 (07.02.00)	**Priority date** (day/month/year) 05 February 1999 (05.02.99)
Applicant DA SILVA MARQUES, Paulo, Vicente et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

04 September 2000 (04.09.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

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PATENT COOPERATION TREATY

REC'D 29 MAY 2001
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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P23051A/VSL/CLF/PPP		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/00322	07/02/2000	05/02/1999
International Patent Classification (IPC) or national classification and IPC G02B6/13		
Applicant THE UNIVERSITY COURT OF THE UNIVERSITY OF et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 12 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
04/09/2000	25.05.2001
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized officer Jakober, F Telephone No. +31 70 340 3652

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/00322

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-21	as originally filed	

Claims, No.:

1-80	with telefax of	06/02/2001

Drawings, sheets:

1/3-3/3	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-80
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-80
Industrial applicability (IA)	Yes:	Claims	1-80
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1: JP(A) 59137346
D2: Ieee Photonics Technology Letters,us,ieee Inc. New York (01-08-1992), 4(8), 875-877
D3: IBM Technical Disclosure Bulletin,us,ibm Corp. New York (01-08-1990), 33(3A), 199-
D4: JP(A) 60191208
D5: JP(A) 62124511

1. Document D1, which is considered to represent the most relevant state of the art, discloses a waveguide comprising:
- a substrate,
- a lower cladding layer
- a doped waveguide core formed on the lower cladding
- an upper cladding layer embedding the waveguide core
- wherein the waveguide core includes mobile dopant ions which have diffused into the upper and lower cladding layers forming a waveguide core having smooth boundary walls.

from which the subject-matter of claim 1 differs in that the lower and upper cladding layers are doped.

As explained in the description of the application, the doping of the cladding layers permits the control of the dopant diffusion (page 3, line 33 to page 4, line 2 of the description).

However, it is well known to a skilled person, that the diffusion of a dopant in a material depends on the concentration of dopant within this material (see in particular document D2). A skilled person would adjust the concentration depending of the parameters he wants to obtain.

Claim 1 further precises that the lower layer is a deposited layer. This feature is

only an obvious possibility for the fabrication of the lower layer. A deposited layer and the adjustment of the dopant concentration are independent features and their combination does not lead to any particular surprising or unexpected effect. The subject-matter of claim 1 can not be considered as involving an inventive step (Art. 33.2 PCT).

2. For the same reason, the subject-matter of claim 30 does not involve an inventive step.

3. It would appear that the dependent claims do not define subject-matter which is inventive, since their structural features are either known from documents cited in the search report or obvious modifications (see passages cited in the international search report).

Re Item VII

Certain defects in the international application

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1, D2 is not mentioned in the description, nor are these documents identified therein.

2. Independent claims 1 and 30 are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D1) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

3. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

Re Item VIII

Certain observations on the international application

1. The "spirit clause" (page 20 and 21) should have been deleted as its presence in

the description serves only to cast unnecessary doubt upon the intended scope of the claims (art. 6 PCT)

2. As they refer to a buffer layer, claims 7, 8, 9 should have been dependent on claim 5 and claims 36, 42, 43, 44 on claim 35. Claim 62 should also have been dependent on claims referring to a buffer layer. This inconsistency in the claim dependency leads to unclarity (Art. 6 PCT).

1 A waveguide for an optical circuit comprising:

a substrate;

a deposited doped lower cladding layer;

a doped waveguide core formed from a layer of doped material deposited on the lower cladding layer; and

a deposited doped upper cladding layer embedding the waveguide core;

wherein the waveguide core includes mobile dopant ions which have diffused from the deposited doped material of the waveguide core into the upper cladding layer and the lower cladding layer to form an ion diffusion region around said doped waveguide core such that the waveguide core boundary walls are substantially smooth.

2. A waveguide as claimed in Claim 1, wherein the ion diffusion region is isotropic with respect to the waveguide core, such that the waveguide core is substantially symmetric about the core axis.

3. A waveguide as claimed in either Claim 1 or Claim 2, wherein the ion diffusion region surrounding the waveguide core forms a substantially rounded waveguide core.

4. A waveguide as claimed in Claim 3, wherein the rounded waveguide core is elliptical or circular in cross-section.

5. A waveguide as claimed in any one preceding claim, further including a buffer layer formed on the substrate and wherein the lower cladding layer is formed on the buffer layer.

6. A waveguide as claimed in any one preceding claim, wherein the substrate comprises silicon and/or silica and/or sapphire.

7. A waveguide as claimed in Claim 6, wherein said buffer layer includes a thermally oxidised layer of the substrate.

8. A waveguide as claimed in any preceding claim, wherein the buffer layer comprises doped silica.

9. A waveguide as claimed in any preceding claim, wherein the thickness of the buffer layer is in the range 0.2 m to 20 m.

10. A waveguide as claimed in any preceding claim, wherein the lower cladding layer comprises doped silica.

11. A waveguide as claimed in any preceding claim, wherein the lower cladding layer includes at least one Phosphorus oxide and/or at least one Boron oxide.

12. A waveguide as claimed in Claim 11, wherein the lower cladding layer includes at least one Phosphorus oxide and at least one Boron oxide and wherein the Phosphorus oxide to Boron oxide ratio is such that the lower cladding layer refractive index is substantially equal to the refractive index of the buffer layer.

13. A waveguide as claimed in any preceding claim, wherein the lower cladding layer includes doped silica, at least one Phosphorus oxide and at least one Boron oxide and wherein the silica:Phosphorus oxide:Boron oxide ratio is in

the range of 75 to 95 wt% silica:1 to 7 wt% Phosphorus oxide:4 to 18 wt% Boron oxide.

14. A waveguide as claimed in Claim 13, wherein the lower cladding layer has a silica:Phosphorus oxide:Boron oxide ratio in the range of 80 to 90 wt% silica:2.5 to 6 wt% Phosphorus oxide:7.5 to 14 wt% Boron oxide.

15. A waveguide as claimed in Claim 14, wherein the lower cladding layer has a silica; to Phosphorus oxide; to Boron oxide ratio of 82 wt% silica; to 5 wt% Phosphorus oxide; to 13 wt% Boron oxide.

16. A waveguide as claimed in any preceding claim, wherein the thickness of the lower cladding layer is 1 m to 20 m.

17. A waveguide as claimed in any preceding claim, wherein the waveguide core comprises doped silica.

18. A waveguide as claimed in any preceding claim, wherein said mobile dopant ions of the waveguide core include Phosphorus and/or Fluorine and/or compounds of these elements.

19. A waveguide as claimed in any preceding claim, wherein dopant ions of the waveguide core include Phosphorus and/or Fluorine and/or Aluminium and/or Boron and/or Germanium and/or Tin and/or Titanium and/or compounds of these elements.

20. A waveguide as claimed in any preceding claim, wherein the waveguide core includes Phosphorus oxide and/or Boron oxide.

21. A waveguide as claimed in Claim 20, wherein the waveguide core comprises P_2O_5-SiO_2.

22. A waveguide as claimed in any preceding claim, wherein the refractive index of the waveguide core differs from that of the lower cladding layer by at least 0.05%.

23. A waveguide as claimed in any preceding claim, wherein the waveguide core includes silica, and at least one Phosphorus oxide and wherein the silica to Phosphorus oxide ratio is in the range of 75 to 95 wt% silica to 5 to 25 wt% Phosphorus oxide.

24. A waveguide as claimed in Claim 23, wherein the waveguide core has a silica to Phosphorus oxide ratio of 80 wt% silica to 20 wt% Phosphorus oxide.

25. A waveguide as claimed in any preceding claim, wherein the thickness of the waveguide core is in the range 2 m to 60 m.

26. A waveguide as claimed in Claim 25, wherein the thickness of the waveguide core is 6 m.

27. A waveguide as claimed in any preceding claim, wherein the lower cladding layer and the upper cladding layer refractive indices are substantially equal.

28. A waveguide as claimed in any preceding claim, wherein the lower cladding layer and the upper cladding layer comprise the same material.

29. A waveguide as claimed in any preceding claim, wherein the waveguide core has a mobile ion dopant concentration higher than the mobile ion dopant concentration of the lower cladding layer or the upper cladding layer.

30. A method of fabricating a waveguide comprising the steps of:

providing a substrate;

forming a doped lower cladding layer by deposition;

forming a doped core layer deposited on the lower cladding layer;

forming a waveguide core from the core layer;

depositing a doped upper cladding layer to embed the waveguide core; and

causing mobile ion dopants included in the core layer to undergo diffusion from the waveguide core into the surrounding upper cladding layer and lower cladding layer to form an ion diffusion region around the waveguide core such that the waveguide core boundary walls are substantially smooth.

31. A method as claimed in Claim 30, wherein the diffusion of the said mobile dopant ions from the waveguide core is such that a waveguide core is formed which is substantially symmetric about the core axis.

32. A method as claimed in either Claim 30 or 31, wherein the diffusion of the said mobile dopant ions from the waveguide core swells the boundary walls of the waveguide core.

33. A method as claimed in Claim 32, wherein the diffusion of the said mobile dopant ions swells the boundary walls of the waveguide core to form a substantially rounded waveguide core.

34. A method as claimed in Claim 33, wherein the rounded waveguide core is elliptical or circular in cross-section.

35. A method as claimed in any one of Claims 30 to 34, and including the step of forming a buffer layer on the substrate.

36. A method as claimed in Claim 35, wherein the lower cladding layer is formed on said buffer layer.

37. A method as claimed in any of Claims 30 to 36, wherein the steps of forming each of the lower cladding layer, the core layer and the upper cladding layer comprise the steps of:

depositing each layer; and

at least partially consolidating each layer.

38. A method as claimed in Claim 37, wherein any of the lower cladding layer, the core layer and the upper cladding layer partially consolidated after deposition is fully consolidated with the full consolidation of any other of

the lower cladding layer, the core layer or the upper cladding layer.

39. A method as claimed in any of Claims 30 to 38, wherein the diffusion of mobile ion dopants in the core layer occurs during the consolidation of the lower cladding layer and/or the upper cladding layer.

40. A method as claimed in any of Claims 30 to 39 further comprising at least one thermal processing step after the formation of the upper cladding layer, wherein during said thermal processing of the waveguide the mobile ion dopants in the core layer undergo diffusion into the surrounding layers.

41. A method as claimed in any of Claims 30 to 40, wherein the substrate comprises silicon and/or silica and/or sapphire.

42. A method as claimed in any of Claims 30 to 41, wherein the buffer layer includes a thermally oxidised layer of the substrate.

43. A method as claimed in any of Claims 30 to 42, wherein the buffer layer comprises doped silica.

44. A method as claimed in any of Claims 30 to 43, wherein the thickness of the buffer layer formed is in the range of 0.2 m to 20 m.

45. A method as claimed in any one of Claims 30 to 44, wherein the lower cladding layer comprises doped silica.

46. A method as claimed in any one of Claims 30 to 45, wherein the lower cladding layer includes at least one Phosphorus oxide and/or Boron oxide.

47. A method as claimed in Claim 46, wherein the lower cladding layer includes at least one Phosphorus oxide and at least one Boron oxide and wherein the Phosphorus oxide to Boron oxide ratio is such that the lower cladding layer refractive index is substantially equal to the refractive index of the buffer layer.

48. A method as claimed in any of Claims 30 to 47, wherein the lower cladding layer includes silica, at least one Phosphorus oxide and at least one Boron oxide and wherein the silica; to Phosphorus oxide; to Boron oxide ratio in the range of 75 to 95 wt% silica; to 1 to 7 wt% Phosphorus oxide; to 4 to 18 wt% Boron oxide.

49. A method as claimed in Claim 48, wherein the lower cladding layer has a silica; to Phosphorus oxide; to Boron oxide ratio in the range of 80 to 90 wt% silica; to 2.5 to 6 wt% Phosphorus oxide; to 7.5 to 14 wt% Boron oxide.

50. A method as claimed in Claim 51, wherein the lower cladding layer has a silica; to Phosphorus oxide; to Boron oxide ratio of 82 wt% silica; to 5 wt% Phosphorus oxide; to 13 wt% Boron oxide.

51. A method as claimed in any of Claims 30 to 50, wherein the thickness of the lower cladding layer is 1 m to 20 m.

52. A method as claimed in any of Claims 30 to 51, wherein the core layer comprises doped silica.

53. A method as claimed in any of Claims 30 to 51, wherein said mobile dopant ions of the waveguide core include Phosphorus and/or Fluorine and/or compounds of these elements.

54. A method as claimed in any of Claims 30 to 53, wherein dopant ions of the waveguide core include Phosphorus and/or Fluorine and/or Aluminium and/or Boron and/or Germanium and/or Tin and/or Titanium and/or compounds of these elements.

55. A method as claimed in any of Claims 30 to 54, wherein the core layer includes Phosphorus oxide and/or Boron oxide.

56. A method as claimed in Claim 55, wherein the core layer comprises P_2O_5-SiO_2.

57. A method as claimed in any of Claims 30 to 56, wherein the refractive index of the waveguide core differs from that of the lower cladding layer by at least 0.05%.

58. A method as claimed in any of Claims 30 to 57, wherein the waveguide core includes silica and at least one Phosphorus oxide and wherein the silica to Phosphorus oxide ratio is in the range of 75 to 95 wt% silica to 5 to 25 wt% Phosphorus oxide.

59. A method as claimed in Claim 58, wherein the waveguide core has a silica to Phosphorus oxide ratio of 80 wt% silica to 20 wt% Phosphorus oxide.

60. A method as claimed in any of Claims 30 to 59, wherein the thickness of the waveguide core is in the range 2 m to 60 m.

61. A method as claimed in Claim 60, wherein the thickness of the waveguide core is 6 m.

62. A method as claimed in any of claims 35 to 51, wherein said lower cladding layer and said buffer layer are formed substantially in the same step.

63. A method as claimed in any of claims 37 to 62, wherein the consolidation of the lower cladding layer is at a temperature or temperatures in the range 950°C to 1400°C.

64. A method as claimed in Claim 63, wherein the consolidation of the lower cladding layer is at a temperature or temperatures in the range 1100°C to 1350°C.

65. A method as claimed in any of Claims 37 to 64, wherein the consolidation of the core layer is at a temperature or temperatures in the range 950°C to 1400°C.

66. A method as claimed in Claim 65, wherein the consolidation of the core layer is at a temperature or temperatures in the range 1100°C to 1385°C.

67. A method as claimed in any of Claims 37 to 66, wherein the consolidation of the upper cladding layer is at a temperature or temperatures in the range 950°C to 1400°C.

68. A method as claimed in Claim 67, wherein the consolidation of the upper cladding layer is at a temperature or temperatures in the range 1100°C to 1350°C.

69. A method as claimed in any of Claims 37 to 68, wherein the temperature or temperature range at which the lower cladding layer is consolidated is greater than the temperature or temperature range at which the core is consolidated.

70. A method as claimed in any of Claims 37 to 69, wherein the temperature or temperature range at which the upper cladding layer is consolidated is substantially equal to the temperature or temperature range at which the core layer is consolidated.

71. A method as claimed in any of Claims 37 to 69, wherein at least one of the lower cladding layer, the core layer, and the upper cladding layer is deposited by a Flame Hydrolysis Deposition process and/or Chemical Vapour Deposition process.

72. A method as claimed in Claim 71, wherein the Chemical Vapour Deposition process is a Low Pressure Chemical Vapour Deposition process or a Plasma Enhanced Chemical Vapour Deposition process.

73. A method as claimed in any of Claims 37 to 72, wherein the consolidation is by fusing using a Flame Hydrolysis Deposition burner.

74. A method as claimed in any of Claims 37 to 72, wherein the consolidation is by fusing in a furnace.

75. A method as claimed in either of Claims 73 or 74, wherein the step of fusing the lower cladding layer and the step of fusing the core layer are performed simultaneously.

76. A method as claimed in any of Claims 30 to 75, wherein the ion diffusion region is isotropic with respect to the waveguide core.

77. A method as claimed in any of Claims 30 to 76, wherein the waveguide core formed from the core layer is square or rectangular in cross-section.

78. A waveguide as claimed in any one of Claims 1 to 29, wherein the waveguide core formed from the core layer is square or rectangular in cross-section.

79. A method as claimed in any of Claims 30 to 78, wherein the waveguide core is formed from the core layer using a dry etching technique and/or a photolithographic technique and/or a mechanical sawing process.

80. A method as claimed in Claim 79, wherein the dry etching technique comprises a reactive ion etching process and/or a plasma etching process and/or an ion milling process.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
P23051A/VSL/CLF/PPP		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 00322	07/02/2000	05/02/1999
Applicant		
THE UNIVERSITY COURT OF THE UNIVERSITY OF et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2e

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/00322

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/13

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 008, no. 260 (C-254), 29 November 1984 (1984-11-29) & JP 59 137346 A (NIPPON DENSHIN DENWA KOSHA), 7 August 1984 (1984-08-07) abstract ---	1-80
Y	SCHMIDTCHEN J ET AL: "GERMANIUM-DIFFUSED WAVEGUIDES IN SILICON FOR = 1.3 UM AND = 1.55 UM WITH LOSSES BELOW 0.5 DB/CM" IEEE PHOTONICS TECHNOLOGY LETTERS,US,IEEE INC. NEW YORK, vol. 4, no. 8, 1 August 1992 (1992-08-01), pages 875-877, XP000293620 ISSN: 1041-1135 the whole document --- -/--	1-80

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 May 2000	24/05/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/00322

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"BURIED TI IN-DIFFUSED WAVEGUIDE ON LITHIUM NIOBATE" IBM TECHNICAL DISCLOSURE BULLETIN,US,IBM CORP. NEW YORK, vol. 33, no. 3A, 1 August 1990 (1990-08-01), page 199 XP000123902 ISSN: 0018-8689 the whole document ---	1-80
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 045 (P-430), 21 February 1986 (1986-02-21) & JP 60 191208 A (SHIYOUJIROU KAWAKAMI;OTHERS: 01), 28 September 1985 (1985-09-28) abstract ---	1-80
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 342 (P-635), 10 November 1987 (1987-11-10) & JP 62 124511 A (NIPPON TELEGR & TELEPH CORP), 5 June 1987 (1987-06-05) abstract -----	1-80

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/00322

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 59137346 A	07-08-1984	JP 1518949 C	29-09-1989
		JP 63065619 B	16-12-1988
JP 60191208 A	28-09-1985	JP 1830657 C	15-03-1994
		JP 5031123 B	11-05-1993
JP 62124511 A	05-06-1987	JP 2622108 B	18-06-1997